FINAL
BASELINE ECOLOGICAL RISK ASSESSMENT REPORT

FOR THE
GULFCO MARINE MAINTENANCE
SUPERFUND SITE
FREEPORT, TEXAS

PREPARED BY:

URS Corporation
10550 Richmond Avenue, Suite 155
Houston, Texas 77042

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AST – Aboveground Storage Tank

AVS – Acid Volatile Sulfide

BCMCD - Brazoria County Mosquito Control Department

BERA – Baseline Ecological Risk Assessment

COPEC – Chemical of Potential Ecological Concern

DDT – Dichlorodiphenyltrichloroethane

DQO – Data Quality Objective

DUS – Data Usability Summary

DW – dry weight

EPA – United States Environmental Protection Agency

ERL - Effects Range-Low

ERM – Effects Range-Median

FSP – Field Sampling Plan

GRG - Gulfco Restoration Group

HPAH – High Molecular Weight Polycyclic Aromatic Hydrocarbons

HRS – Hazard Ranking Score

HQ – Hazard Quotient

kg – kilogram

L - liter

LC_{50} – Median Lethal Concentration

mg – milligram

MLR – Multiple Linear Regression

NOAA – National Oceanic and Atmospheric Administration

NPL – National Priorities List

PAH – Polycyclic Aromatic Hydrocarbon

PSCR - Preliminary Site Characterization Report

QAPP – Quality Assurance Project Plan

RI/FS – Remedial Investigation/Feasibility Study

SAP – Sampling and Analysis Plan

SEM – Simultaneously Extracted Metals

SLERA – Screening-Level Ecological Risk Assessment

SMDP – Scientific/Management Decision Point

SOP – Standard Operating Procedure

SOW – Statement of Work

TCEQ – Texas Commission on Environmental Quality

TOC – Total Organic Carbon

TPWD – Texas Parks and Wildlife Department

USFWS – United States Fish and Wildlife Service

UAO - Unilateral Administrative Order

EXECUTIVE SUMMARY

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April 15, 2011 (Rev 1)

The United States Environmental Protection Agency (EPA) named the former site of Gulfco Marine Maintenance, Inc. in Freeport, Brazoria County, Texas (Site) to the National Priorities List (NPL) in May 2003. All of the ecological risk assessment activities at the Site were performed under the EPA's 8 step guidance (EPA, 1997), and with the submittal of this Final Baseline Ecological Risk Assessment (BERA) all 8 steps have been completed. The first phase in the ecological risk process, the Screening-Level Ecological Risk Assessment (SLERA), concluded that there were no upper trophic level risks, but there was a potential for adverse ecological effects to soil- and sediment-dwelling invertebrates, and a more thorough assessment was warranted (PBW, 2010). The Final BERA Work Plan & Sampling and Analysis Plan (SAP) and Final BERA Problem Formulation were submitted to the EPA on June 22, 2010 and approved (with modifications) by the EPA on August 4, 2010 (URS, 2010a; URS 2010b). The BERA Work Plan and SAP described a study to assess site-specific toxicity to invertebrates in the North Area soils, wetland sediments, Intracoastal Waterway sediments, and surface water from the wetland area. Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments. A 21-day whole sediment/soil toxicity test using *Neanthes arenaceodentata* was applied to the North Area soils. The bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) and assessed at a 48-hour duration. All of the BERA sediment and soil sample locations were chosen based on a concentration gradient of the chemicals of potential ecological concern (COPECs) identified in the SLERA.

The evaluation of toxicity and analytical data showed that the most relevant comparison was between Site and reference sample locations. This approach allows for a comparison of locations that exhibit similar environmental conditions, except for the presence of Site-related COPECs. Ultimately, it was determined that there is no statistically significant difference in the toxicity observed in samples collected at the reference locations and the Site for sediment/soil exposure and that there was no toxicity associated with the surface water locations. Because of the lack of evidence of Site-related toxicity, development of ecologically-based remediation goals is not necessary.

1.0 INTRODUCTION

The United States Environmental Protection Agency (EPA) named the former site of Gulfco Marine Maintenance, Inc. in Freeport, Brazoria County, Texas (Site) to the National Priorities List (NPL) in May 2003. The EPA issued a modified Unilateral Administrative Order (UAO), effective July 29, 2005, which was subsequently amended effective January 31, 2008. The UAO required Respondents to conduct a Remedial Investigation and Feasibility Study (RI/FS) for the Site. Pursuant to Paragraph 37(d)(x) of the Statement of Work (SOW) for the RI/FS, included as an attachment to the UAO, a May 3, 2010 Final Screening-Level Ecological Risk Assessment (SLERA) was prepared for the Site (PBW, 2010). The Scientific/Management Decision Point (SMDP) provided in the Final SLERA concluded that the information presented therein indicated a potential for adverse ecological effects to soil- and sediment-dwelling invertebrates, and a more thorough assessment was warranted. The Final Baseline Ecological Risk Assessment (BERA) Work Plan & Sampling and Analysis Plan (SAP) and Final BERA Problem Formulation were submitted to the EPA on June 22, 2010 and approved with modifications by the EPA on August 4, 2010. The requested modifications were submitted to the EPA on September 2, 2010 (URS, 2010a; URS 2010b).

Following acceptance of the Final BERA Work Plan & SAP (URS, 2010a), a sixty (60) calendar day schedule for sample collection, laboratory analysis, and data validation was required. The BERA 60-Day deliverable, which was submitted to the EPA on October 4, 2010, summarized the field activities, toxicity testing, chemical analyses and data validation. As per the SOW paragraph 36(d), a Draft Preliminary Site Characterization Report (PSCR) was submitted to the EPA within thirty (30) calendar days following receipt of all validated laboratory data as provided in the BERA 60-Day deliverable. The Final PSCR was approved by EPA on December 8, 2010 (URS, 2010c). In accordance with SOW Paragraph 37(d) (xviii), this Draft BERA Report is submitted to EPA within sixty (60) days following receipt of EPA approval of the Final PSCR. This Draft BERA Report was prepared by URS Corporation (URS) on behalf of LDL Coastal Limited LP (LDL), Chromalloy American Corporation (Chromalloy), The Dow Chemical Company (Dow), and Parker Drilling Company, which, has recently reached an agreement to participate with the Respondents in the work being performed at the Site, collectively, the Gulfco Restoration Group (GRG).

1.1 REPORT PURPOSE

The objective of this BERA Report is to characterize the Site-specific risks using recently-collected samples of surface soil, surface sediment, and surface water in accordance with the study design identified in the Final BERA Work Plan and SAP (URS, 2010a). The PSCR (URS, 2010c) and the BERA Report also serve to supplement the Nature and Extent Data Report (PBW, 2009).

1.2 SITE SETTING AND HISTORY

The Site is located in Freeport, Brazoria County, Texas on the Gulf Coast approximately 62 miles south of Houston, Texas. The street address is 906 Marlin Avenue, also referred to as County Road 756 (Figure 1). The Site consists of approximately 40 acres within the 100-year coastal floodplain along the north bank of the Intracoastal Waterway between Oyster Creek (approximately one mile to the east) and the Texas Highway 332 Bridge (approximately one mile to the west). The Site includes approximately 1,200 feet of shoreline on the Intracoastal Waterway, the third busiest shipping canal in the US (TxDOT, 2001) that, on the Texas Gulf Coast, extends 423 miles from Port Isabel to West Orange.

Marlin Avenue divides the Site into two primary areas (Figure 2). For the purpose of descriptions in this report, Marlin Avenue is approximated to run due west to east. The property to the north of Marlin Avenue (the North Area) consists of undeveloped land and capped surface impoundments, while the property south of Marlin Avenue (the South Area) was developed for industrial uses with multiple structures, a dry dock, an aboveground storage tank (AST) tank farm, and two barge slips connected to the Intracoastal Waterway.

Adjacent property to the north, west, and east of the North Area is undeveloped. Adjacent property to the east of the South Area is currently used for industrial purposes while the property to the west is currently vacant and previously served as a commercial marina. The Intracoastal Waterway bounds the Site to the south. Residential areas are located south of Marlin Avenue, approximately 300 feet west of the Site, and 1,000 feet east of the Site.

During the 1960s, the Site was used for occasional welding but there were no on-site structures (Losack, 2005). According to the Hazard Ranking Score (HRS) Documentation (TNRCC, 2002), at least three different owners from 1971 through 1999 used the Site as a barge cleaning facility. Beginning in 1971, according to the HRS documentation, barges were brought to the facility and cleaned of waste oils, caustics and organic chemicals, with these products stored in on-site tanks and later sold (TNRCC, 2002). Sandblasting and other barge repair/refurbishing activities were also reported to have occurred on the Site. At times during the operation, according to the HRS documentation, wash waters were reportedly stored either on a floating barge, in on-site storage tanks, and/or in surface impoundments on Lot 56 of the Site. The surface impoundments were closed under the Texas Water Commission's (TCEQ predecessor agency) direction in 1982 (Carden, 1982).

Aerial spraying for mosquito control of the wetland areas north of Marlin Avenue, including the North Area, has historically been and continues to be performed by the Brazoria County Mosquito Control District and its predecessor agency, the Brazoria County Mosquito Control Department (both referred to hereafter as BCMCD). Aerial spraying for mosquito control has been performed over rural areas in the county since 1957 (Lake Jackson News, 1957). Historically, aerial spraying of a DDT solution in a "clinging light oil base" was performed from altitudes of 50 to 100 feet (Lake Jackson News, 1957). Recently, BCMCD has been using Dibrom®, an organophosphate insecticide, with a diesel fuel carrier through a fogging atomizer application (Brazoria County Facts, 2006, 2008a, 2008b), as well as other compounds such as Scourge™, Kontrol 30-30, and Fyfanon® (personal communication between Gary Miller [EPA] and Fran Henderson [BCMCD], October 27, 2010). Truck-based spraying has also been performed along Marlin Avenue. Both types of spraying were observed during the performance of Site RI activities.

1.3 ENVIRONMENTAL SETTING

The Site resides in the Brazos River Delta in the Mid-Coast Barrier Islands and Coastal Marshes ecological subregion, one of ten in the larger Texas-Louisiana Coastal Plains ecoregion (CEC, 1997). The subregion is characterized by flat topography and a diverse array of hydrological features such as lakes, rivers, bayous, marshes, mud flats, and bays. The soils are very clayey and poorly drained with a shallow water table and support a variety of saltwater and freshwater grassland species. Precipitation in the ecoregion may be up to 55 inches (140 cm), temperatures average 68-70° F (20-21° C), and the growing season lasts 280-320 days.

Wildlife common to the larger ecoregion are coyote, river otter, the piglike collared peccary (javelina), swamp rabbit, plains pocket gopher, reddish egret, white-faced egret, roseate spoonbill, white-tailed hawk, American alligator, Mediterranean gecko, Texas blind snake, Gulf Coast toad, and diamondback terrapin.

Some of the North Area is upland created from dredge spoil, but most of this area is considered wetlands, per the United States Fish and Wildlife Service (USFWS) Wetlands Inventory Map (USFWS, 2008). The most significant surface features in the North Area are two ponds (the Fresh Water Pond and the Small Pond) and the capped surface impoundments (Figure 2). The capped surface impoundments and the former parking area south of the impoundments comprise the vast majority of the upland area within the North Area.

According to the United States Department of Agriculture (USDA) County Soils Maps (USDA, 1981), surface soils north of Marlin Avenue are classified as Velasco clays. The soil type is listed on the state and federal soils lists as a hydric soil. The Velasco series consists of very deep, nearly level, very poorly drained saline soils. These soils formed in thick, recent clayey sediments near the mouth of major rivers and streams draining into the Gulf of Mexico. They occur on level to slightly depressed areas near sea level and are saturated most of the year. The slope is generally less than one percent.

Field observations during the RI indicate that the North Area wetlands are irregularly flooded. Water can accumulate to a depth of one foot or more during extreme high tide conditions, storm surge events (such as Hurricane Ike in September 2008), and/or in conjunction with surface flooding of Oyster Creek northeast of the Site. Due to a very low topographic slope and low permeability surface sediments, the wetlands also drain very poorly and retain surface water after major rainfall events. Under normal tide conditions and during periods of normal or below normal rainfall, standing water outside of the two ponds is typically limited to a small, irregularly-shaped area immediately north of the Fresh Water Pond and similar areas immediately south and southeast of the capped surface impoundments. Depending on rainfall and tide conditions, these areas can often be completely dry.

Water in the Fresh Water Pond is approximately 4 to 4.5 feet deep and is relatively brackish (PBW, 2009). This pond appears to be a borrow pit created by the excavation of soil and sediment as suggested by the well-defined pond boundaries and relatively stable water levels.

The small irregularly shaped area immediately north of the Fresh Water Pond is a salt panne, a shallow depression that retains water for short periods of time such that salt accumulates to high levels over multiple tidal cycles. During the field sampling in August 2010, Benchmark Ecological Services, Inc. measured a surface water salinity of 43 parts per thousand (‰) from this area (sample EWSW01).

The Small Pond is a very shallow depression located in the southeastern corner of the North Area. The water depth was approximately 0.2 feet when sampled in July 2006 and nearly dry when sampled in June 2008. The Small Pond is not influenced by daily tidal fluctuations and behaves in a manner consistent with the surrounding wetland; that is, it dries up during dry weather, but retains water after rainfall and extreme tidal events. During the field sampling in August 2010, a surface water salinity of 42‰ was measured in the Small Pond (sample EWSW04). The surface water salinity from the area south of the impoundments (sample EWSW03) was approximately 27‰ in September 2010. These salinities were consistent with as-received salinities measured in the laboratory by PBS&J Environmental Toxicology Laboratory (approximately 40‰, 39‰, and 30% for EWSW01, EWSW04, and EWSW03, respectively).

As discussed above, the wetlands area is indicative of marsh flats, which contain shallow pools and salt pannes. A salt panne is periodically flooded by tidal events that bring fresh sea-borne nutrients, small fish, and invertebrates. When these shallow pools evaporate, salty brine remains. These areas in the wetlands often dry out completely, creating even harsher conditions. When the seawater evaporates, the salts remain and accumulate over many tidal cycles. The difficult environs of the salt panne usually have soils that are frequently waterlogged, making them devoid of oxygen. The high salt concentrations, waterlogged soils, and warm waters associated with salt pannes mean that not many plant species can survive and the biological diversity is low. The plants species observed growing in the North Area wetlands and uplands are listed below with a brief description from the Lady Bird Johnson Wildflower Center Native Plant database (2011):

- Sea ox-eye daisy (Borrichia frutescens) – This is a commonly found shrub on the edges of saltmarshes and brackish marshes. It is a salt-tolerant member of the aster family.
- Saltgrass (*Distichlis spicata)* – This erect, warm-season grass forms dense colonies up to 3 feet high. The grass adapts to drier soils including silts, clays and sands. It prefers wet, saline or alkaline soils.
- Marsh elder (*Iva frutescens)* – This is a succulent, bushy-branched shrub, 2-10 feet tall. The native habitat is saline marshes and shores.
- Western baccharis (*Baccharis halimifolia*) – This plant is also known as sea-myrtle, consumptionweed, groundseltree, salt marsh elder or salt bush. The 6- to 12-foot deciduous shrub bears gray-green leaves. It is salt-tolerant and fast growing.
- Shoregrass (*Monanthocloe littoralis*) – This plant is found in coastal and salt marshes.
- Spike sedge (*Eleocharis* sp.) – This plant is also known as spikerush.
- Sturdy bulrush (*Schoenoplectus robustus*) – This plant is a member of the sedge family and their seeds are common foods of ducks and marsh birds. Their native habitat is brackish or coastal marshes.
- Saltmeadow cordgrass (*Spartina patens)* –This member of the grass family prefers wet, sandy soil and is often used for beach front stabilization.
- Gulf cordgrass *(Spartina spartinae)* – Gulf cordgrass is a perennial plant and is found in tidal flats, lagoons and marshes. It prefers sandy soil and is saline-tolerant.
- Turtleweed (*Batis maritima)* - Also known as seaside saltwort, this plant is a perennial shrub. Its native habitat includes tidal flats and lagoons. It grows in many different types of soil and is saline tolerant.

- Dwarf saltwort *(Salicornia bigelovii)* – This plant is a native annual herb/forb.

- Wolfberry *(Lycium carolinianum)* – This plant is also known as the Carolina wolfberry, Carolina desert-thorn, creeping wolfberry or Christmas berry. It is native in coastal plains from South Carolina to Texas and is considered a perennial shrub. It is found in ditches, ravines, depressions, swamps and marshes. It tolerates saline conditions.

- Annual marsh elder *(Iva annua)* - This plant is a native annual herb/forb.

The use of the Site by wildlife is limited by the hard, compacted surface soils covering a portion of the Site, or the clay-dominated subsurface soils found under most of the Site. Burrowing animals observed at the Site include field mice, rat snakes, fiddler crabs, and ghost crabs. The distribution of burrowing organisms is typically restricted by the availability of food and soil characteristics. Most species of burrowing mammals, reptiles and crustaceans prefer to excavate their tunnels in sandy loam or sandy clay, and have limited success in hard, compacted surface soils or soils containing rocks and shell (Crane, 1975; Grimes, *et al*., 1989). Two species of fiddler crabs can be found at the Site. Mud fiddler crab (*Uca rapax*) burrows in muddy marsh sediment that is relatively free of plant roots and gravel. The sand fiddler crab (*Uca pugilator*) prefers sandy soils and is generally found near the shoreline. Other crustaceans found at the Site were fiddler crabs (*Uca panacea*) and hermit crabs (*Clibanarius vittatus*).

In regards to the potential presence of threatened and endangered species, the SLERA (PBW, 2010) documented that the United States Fish and Wildlife Service (USFWS) was consulted (USFWS, 2005a, b and c) and information obtained from both the USFWS and Texas Parks and Wildlife Department (TPWD). No threatened or endangered species have been observed at the Site but they are known to live in or on, or migrate through the Texas Gulf Coast and estuarine wetlands (TPWD, 2005). Because the SLERA concluded that there were no upper trophic level risks and threatened and endangered species have not been observed at the Site, this BERA focused on potential impacts to receptors where adverse risk was predicted in the SLERA (PBW, 2010) (i.e., soil/sediment invertebrates and water column receptors).

1.4 REPORT ORGANIZATION

Section 1 presents the report purpose, site setting and history, and environmental setting. Sections 2 through 6 are organized based on the EPA's Ecological Risk Assessment Guidance for Superfund (1997). Section 2 presents a summary of the SLERA, BERA Problem Formulation and BERA Work Plan and SAP representing Steps 1 – 5 of the EPA process. Section 3 presents the site investigation and data analysis phase of the BERA (Step 6). The Risk Characterization, with a focus on risk estimation and risk description, is presented in Section 4. Section 5 presents the uncertainty analysis. Sections 4 and 5 together represent Step 7 of the EPA process. Section 6 presents the framework for the risk management discussion for the BERA (Step 8). References are listed in Section 7. Environmental chemistry results are presented in Appendix A (i.e., a data usability summary [DUS], analytical data summary tables, data validation checklists, and associated laboratory reports from Columbia Analytical Services). Toxicity testing results are provided in Appendix B (i.e., a DUS and associated laboratory reports from PBS&J Environmental Toxicology Laboratory). The results of a multivariate statistical analysis are presented in Appendix C.

2.0 SUMMARY OF THE SLERA, BERA PROBLEM FORMULATION, AND BERA WORK PLAN (STEPS 1-5)

The SLERA (PBW, 2010), BERA Problem Formulation (URS, 2010b) and BERA Work Plan & SAP (URS, 2010a) were finalized in 2010. This section presents a summary of those documents as it pertains to the problem formulation of the BERA.

2.1 SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT (STEPS 1 AND 2)

The purpose and scope of the SLERA was to summarize the analytical data for environmental media sampled during the RI and to complete Steps 1 and 2 of the EPA's Ecological Risk Assessment process based on those data. The SLERA was a conservative assessment and served to evaluate the need and, if required, the level of effort necessary to conduct a baseline ecological risk assessment. Per the EPA guidance (1997), the SLERA provided a general indication of the potential for ecological risk (or lack thereof) and was conducted for several purposes including: 1) to estimate the likelihood that a particular ecological risk exists; 2) to identify the need for site-specific data collection efforts; or 3) to focus site-specific ecological risk assessments where warranted.

The SLERA (PBW, 2010) compared maximum concentrations of the COPECs to protective ecological benchmarks for direct contact toxicity. The SLERA concluded that there may be the potential for adverse impacts to sedentary biota communities in surface soil from several COPECs that exceeded a Hazard Quotient (HQ) of 1 in the South Area and North Area. In addition, the SLERA indicated a potential for localized adverse ecological effects to sedentary biota communities in sediment. Concentrations of the COPECs that exceeded the midpoint of the effects range–low and effects range-median (ERL and ERM) concentration levels in sediment of the North Area wetlands, Intracoastal Waterway and the Ponds were predicted to have toxic effects. The SLERA also concluded that there was a possible risk from direct toxicity to aquatic species, including fish, due to acrolein and dissolved copper in the surface water of the North Area wetlands and silver in the surface water of the Ponds and the Background Intracoastal Waterway area. It should be noted that the SLERA determined that adverse effects resulting from soil ingestion, sediment ingestion, surface water and/or food chain exposures to higher trophic-level receptors were unlikely or insignificant because HQs for higher trophic-level receptors were less than 1.

2.2 BASELINE ECOLOGICAL RISK ASSESSMENT PROBLEM FORMULATION (STEP 3)

Following completion of the SLERA, the BERA Problem Formulation was conducted to identify the specific ecological issues at the Site and determine the scope and goals of the BERA in accordance with Paragraph 37(d)(xi) (Step 3) of the SOW for the RI/FS. The BERA Problem Formulation further refined or identified the COPECs, ecological effects of the COPECs, fate and transport, and assessment endpoints.

Problem formulation included the following:

- Refining the list of COPECs identified in the conclusion of the SLERA;
- Further characterizing the ecological effects of the refined COPEC list;
- Reviewing and refining information on contaminant fate and transport, complete exposure pathways, and ecosystems potentially at risk;
- Determining assessment endpoints (i.e., the specific ecological values to be protected); and
- Developing a conceptual site model with risk questions for the ecological investigation to address.

Steps were taken to refine the COPEC list (i.e., modification of conservative exposure assumptions and review of spatial COPEC distributions) and conduct a literature research on the ecological effects of the refined list of COPECs, as well as their fate and transport characteristics relative to Site conditions. Subsequent to these steps, the following ecosystems were identified as potentially at risk:

- <u>Wetland sediments and surface water.</u> The primary COPECs with HQs greater than 1 in wetland sediment were several polycyclic aromatic hydrocarbons (PAHs). Most of the HQ exceedances for the PAHs were located in three areas: (1) a small area immediately northeast of the capped surface impoundments; (2) a smaller area immediately south of the capped surface impoundments; and (3) at a sample location in the southwest part of the North Area approximately 60 feet north of Marlin Avenue. Other COPECs included the organochlorine pesticides and metabolites 4,4'-DDT, endrin aldehyde, and endrin ketone. The metals that were COPECs included arsenic, copper, lead, nickel, and zinc. Additionally, total acrolein and dissolved copper were surface water COPECs in the wetland area northeast of the capped surface impoundments. The COPECs in the Small Pond included 4,4'-DDT and zinc in the sediments and silver in the surface water.

- Intracoastal Waterway sediment within former Site barge slips. The predominant COPECs in these areas, as reflected by HQ exceedances, were PAHs. The total PAH concentration was highest in the northernmost sample in the western barge slip. In the eastern barge slip, the COPECs were three PAHs, hexachlorobenzene, and the sum of high molecular-weight PAHs (HPAHs). The only organochlorine pesticide COPEC was 4,4'-DDT.

- North Area soils south of the capped surface impoundments. The metals COPECs in this area, where some buried debris was encountered in the shallow subsurface, were barium, chromium, copper, and zinc. Organic COPECs included 4,4'-DDT and Aroclor-1254.

The risk questions developed through the BERA Problem Formulation were:

1. Intracoastal Waterway and Wetlands sediments: Does exposure to COPECs in sediment adversely affect the abundance, diversity, productivity, and function of sediment invertebrates as an aquatic community?

2. Wetlands and Pond surface water: Does exposure to COPECs in surface water adversely affect the abundance, diversity, productivity, and function of water-column invertebrates and fish?

3. North Area soils: Does exposure to COPECs in soil adversely affect the abundance, diversity, productivity, and function of soil invertebrates as a terrestrial community?

Justification for removal of the South Area from the ecological risk process was provided in the approved Final BERA Problem Formulation Report (URS, 2010b) and is summarized here. The South Area of the Site is characterized by the following habitat-related considerations:

1. It is zoned by the City of Freeport as “W-3, Waterfront Heavy”, which provides for commercial and industrial land use, primarily port, harbor, or marine-related activities;

2. A restrictive covenant placed on the deed ensures that future land use for this parcel of land is commercial/industrial;

3. The area does not serve as valuable habitat, foraging area, or refuge for ecological communities, including threatened/endangered or otherwise protected species;

4. The area does not contain consistent and contiguous habitat but, rather, the area is broken up by the presence of concrete slabs, pads, driveways, and areas of compacted shell;

5. The area exhibits minimal ecological functions because of the disturbed nature of the land and historical industrial use of the property and adjacent properties; and

6. There are minimal, if any, attractive features at the South Area that would support a resident wildlife community.

Since the Site was developed in the early 1960s, as described in the Nature and Extent Data Report (PBW, 2009), it has been used for industrial purposes. It is also bounded by former and/or current industrial properties to the east and west. The Site has not been used since approximately 1999 and opportunistic grasses and small shrubs have grown on some portions of the South Area that do not have concrete, oyster shell, or gravel cover. The South Area will be used in the future for commercial/industrial purposes since the barge slips are valuable to many types of businesses in the area, and it is unlikely that the Site will return to “natural” conditions. The evidence indicates that the South Area soils do not represent a valuable ecological resource that warranted further evaluation in order to protect invertebrates such as earthworms and, therefore, there was no further assessment of the South Area soils (URS, 2010b).

2.3 BERA WORK PLAN – STUDY DESIGN AND DATA QUALITY OBJECTIVES (STEP 4)

The BERA Work Plan was prepared to describe the investigation components necessary to complete the BERA. The Work Plan included a Sampling and Analysis Plan (SAP) that established the specific sampling locations, equipment, and procedures to be used during the BERA. The BERA Work Plan & SAP was finalized on September 2, 2010 (URS, 2010a).

The overall objective to be addressed by the BERA is to evaluate the specific contaminants, pathways, and receptors identified in the SLERA as warranting additional investigation. Data Quality Objectives (DQOs) were established for the BERA through the Problem Formulation steps to identify the assessment endpoints and risk questions (Table 1). The DQOs were based on the proposed end uses of data generated from sampling and analytical activities. The DQOs are qualitative and quantitative statements that outline the decision-making process and specify the required data.

2.4 BERA EXPOSURE ANALYSIS

To address the BERA objectives and risk questions listed in the Problem Formulation (URS, 2010b), an investigation program was developed that used multiple lines of evidence including sediment toxicity testing, surface water toxicity testing, measures of COPEC bioavailability, and COPEC concentration data.

The investigation program included bioassays of invertebrates coupled with chemical analyses of soil, sediment, pore water, and surface water. The bioassays, chemical analyses, and determination of COPEC bioavailability represent three lines of evidence that were used to support the conclusions of the BERA. The analyses were selected to incorporate the media, pathways, and COPECs relevant to the assessment endpoints (Table 1). Sampling, analysis, and data evaluation protocols were selected to ensure that the data collected are scientifically defensible and applicable to the BERA objectives. Sample station locations were selected based on COPEC concentrations along a gradient. Sampling locations are provided on Figures 3 through 7.

2.5 FIELD VERIFICATION OF SAMPLING DESIGN (STEP 5)

The purpose of the Field Verification of the Sampling Design (Step 5) is to evaluate the appropriateness and implementability of the testable hypotheses, exposure pathway model, and measurement endpoints created in Steps 3 and 4 (EPA, 1997). There were two significant adjustments to the toxicity testing protocol as discussed below in Section 3.2: 1) the test species for the North Area soil was changed from the earthworm (*Eisenia fetida*) to the polycheate *Neanthes arenaceodentata* and the soils were treated as sediments in the toxicity testing and 2) the surface water test species was changed from Mysid shrimp (*Mysidopsis bahia*) to brine shrimp (*Artemia*). Both of these adjustments were due to the elevated salinity commonly found in the salt panne environment as described in Section 1.3 and were discussed and approved by EPA prior to completing the study.

3.0 SITE INVESTIGATION AND DATA ANALYSIS PHASE (STEP 6)

Field activities and laboratory testing conducted in August and September 2010 to support the BERA are described below. Sample collection methods, pore water extraction method, field measurements procedures, laboratory analytical methods, toxicity testing methods, and data validation procedures were specified in the Field Sampling Plan (FSP) (PBW, 2006a), Quality Assurance Project Plan (QAPP) (PBW, 2006b) and/or Final BERA Work Plan & SAP (URS, 2010a). Appendix A includes the DUS for the chemistry analyses performed by Columbia Analytical Services. Appendix B includes the DUS for the toxicity testing performed by PBS&J Environmental Toxicology Laboratory. BERA field activities were also conducted in accordance with the Site-specific Health and Safety Plan (PBW, 2005).

3.1 ENVIRONMENTAL MEDIA SAMPLING

The initial environmental media sampling to support the BERA began on August 12, 2010 and was completed on August 31, 2010. Samples were analyzed for those COPECs listed in the Final BERA Work Plan & SAP (URS, 2010a). Total organic carbon (TOC) data were obtained for the sediment samples from the wetlands area and the Intracoastal Waterway. Simultaneously-extracted metals, acid volatile sulfides (SEM/AVS) and grain size analysis were obtained for the wetland sediments. Data gathered in the field such as water depth, pH, conductivity, temperature, salinity and dissolved oxygen for water and pH, oxygen reduction potential and temperature are shown on Tables 2 and 3.

The pore water sample EWSED04PW collected on August 27, 2010 could not be analyzed for PAHs due to a laboratory error. Field activities were re-initiated on September 9, 2010 to collect the pore water sample from the same location. While the sampling team was present on the Site, they evaluated whether sufficient pore water was present at EWSED03, EWSED05, and EWSED09 (as well as sufficient surface water from EWSW02 and EWSW03) that had previously been dry. All of these pore water and surface water samples, except for EWSED05PW and EWSW02, were subsequently collected in September 2010. Consistent with the BERA Work Plan & SAP (URS, 2010a), there were no analytical samples formally archived for this project.

3.2 TOXICITY TESTING PROTOCOLS

Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments as described in the Final BERA Work Plan & SAP (URS, 2010a). The sediment toxicity testing was conducted from August 25 through September 22, 2010. Responses of test organisms exposed to laboratory control samples for all of the sediment toxicity tests indicated that the test organisms were of acceptable health. Additionally, the reference and Site toxicant tests were within acceptable quality control parameters. The purpose of the laboratory control tests is to determine the validity of the test. The sediment used for the laboratory controls is taken from the York River in Virginia, processed to remove vegetative matter, and then frozen to remove live indigenous organisms that could prey upon the test species. The effect of freezing the sediments on the health of the test organisms is unknown, although it likely imparts little uncertainty in the analysis since it is commonly performed and follows standard procedures.

Conducting the 28-day earthworm (*Eisenia fetida*) bioassays for North Area soils, as proposed in the Final BERA Work Plan & SAP (URS, 2010a), was problematic given significantly elevated salinity levels in the six (6) Site and three (3) reference soil sample locations. When the earthworms were introduced to the North Area soil samples in the laboratory, there was an immediate avoidance reaction followed by acute mortality in all of the Site and reference location samples. The elevated salinity levels are believed to be due to frequent inundation with estuarine water related to storm events. Also, much of the soil/sediment in the North Area uplands was originally dredge spoils from the Intracoastal Waterway used as fill material. Following discussion and agreement by the EPA on September 3, 2010, an alternative method for the earthworm bioassays was developed. The nine (9) soil samples from this transitional area were treated as sediment by adding synthetic seawater and the polychaete *Neanthes arenaceodentata* was exposed over a 21-day test duration with growth and survival endpoints. According to the National Oceanic and Atmospheric Administration (NOAA), survival and growth endpoints "are about equal sensitivity" for *Neanthes arenaceodentata* (MacDonald et al., 2003). Polychaetes are more phylogenetically and taxonomically similar to earthworms than amphipods, such as *Leptocheirus plumulosus*, and are members of the “sediment-ingesting invertebrate" feeding guild that the earthworm was chosen to represent. The 21-day test duration is conservative given the ephemeral nature of the inundation events at the Site. The North Area soil toxicity testing was conducted from September 10 through October 1, 2010.

Similar to the North Area soils, elevated salinity levels measured in August 2010 were also a concern for surface water samples EWSW01 and EWSW04. As-received salinities of 40‰ and 39‰, respectively, were measured by PBS&J Environmental Toxicology Laboratory and would likely result in significant stress to the mysid shrimp (*Mysidopsis bahia*) proposed in the Final BERA Work Plan & SAP (URS, 2010a). Appendix B contains all of the toxicity laboratory reports that include presentation of chemistry parameters such as salinity and ammonia measurements. As previously discussed, these elevated salinity levels are indicative of a salt panne. Therefore, the bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) that are better suited for high salinities. There are no standard laboratory methods for testing chronic exposures to brine shrimp. Therefore, PBS&J Environmental Toxicology Laboratory developed a standard operating procedure (SOP) for conducting acute tests with a survival endpoint by referencing standard procedures for determining toxicity from produced (oilfield) waters (SPE, 1978). This shortened test protocol, from 7 days to 48 hours, is more representative of the ephemeral nature of surface water in the areas being evaluated and was demonstrated with the toxicity testing to be more reliable as described in more detail in the following paragraph. Use of the alternative species and test protocol was approved by the EPA on September 3, 2010.

The surface water toxicity tests with *Artemia* were conducted three times between September 16 and October 3, 2010. The initial test was potentially affected by a laboratory technician using an incorrect food for the test organisms; however the lab control showed 100% survival at 48 hours. The second test exhibited excessive control mortality (failure) (i.e., less than 90% survival of the control) after 48 hours, and the third test was completed with excessive control mortality (failure) after 96 hours but acceptable lab control survival at 48 hours (90%). The applicability of the 96 hour test duration is questionable. On December 1, 2010, a meeting was held with Texas Commission on Environmental Quality (TCEQ) and EPA where it was decided that the original test duration of 96 hours was not acceptable for this test species and site conditions and that the test duration of 48 hours, as described in the original standard procedure (SPE, 1978), would be the accepted test duration.

For the evaluation of the toxicity of Site sediment and soil samples, the most relevant comparison is to results for reference location samples. This enables the comparison of results between Site samples and reference samples that exhibit similar environmental conditions, but are not influenced by releases from the Site. Note that reference samples may contain background concentrations of one or more naturally occurring metals as well as anthropogenic constituents that are not related to Site activities (EPA, 2002).

3.3 RESULTS OF CHEMICAL ANALYSES AND TOXICITY TESTING

Chemistry data generated from the BERA sampling and analyses were compared to the previously-collected data to evaluate the COPEC concentration gradients across the Site. The 2010 BERA data were also compared to the applicable screening benchmarks as listed in the BERA Work Plan and SAP (Table 6; URS, 2010a). TCEQ (2006) is the primary source for the screening benchmarks. Site investigation activities are described by environmental medium and/or area in the sections below. The following text provides a discussion of the COPEC gradients, screening level and/or reference location concentration (not Site related) exceedances, and corresponding toxicity testing results with supporting tables and figures. The statistical analysis of the toxicity test results is discussed by study area. Table 4 is a summary of the toxicity testing results for each of the study areas without statistical comparison of the Site samples with reference samples; however, note that the toxicity results, such as mean survival and mean growth, are based on multiple replicates of the test chambers per sample. For instance, the *Neanthes arenaceodentata* test was conducted on five (5) replicates of five (5) organisms in each replicate for each sample and the *Leptocheirus plumulosus* test was conducted on five (5) replicates with twenty (20) organisms in each replicate for each sample. The results presented on Tables 4, 5, 6 and 9 and throughout the BERA, should be considered as a mean calculation of the replicates and not a single test result.

The determination of growth for this BERA is based on the dry weight of the surviving organisms divided by the number of surviving organisms. The assessment of biomass (as shown on Tables 4, 5, 6 and 9) is the dry weight of the surviving organisms divided by the initial number of organisms. Growth as presented by biomass is not routinely applied to sediment testing (EPA, 2000) and is therefore not presented as the primary representative of growth in this BERA.

The determination of the statistical comparison is based on the methods outlined in the BERA Work Plan and SAP (URS, 2010a) which describes that significant differences for the toxicity tests are set at P< 0.05. CETIS™v 1.8.04 was used as the statistical package. Additional information on the statistical testing can be found in Appendix B. Discussion of the statistical and biological significance of the data is presented in the following sections.

3.3.1 North Area Soil

North Area soil was evaluated through the collection and analysis of six (6) samples from the Site (NAS01 through NAS06) and three (3) samples from a reference area (NAS07 through NAS 09) (see Figure 3 and Figure 1, respectively). All of the soil samples were collected from the 0 to 0.5-foot depth interval. The COPECs for the North Area soil are as follows:

- 4,4’-DDT;
- Aroclor-1254;
- Barium;
- Chromium;
- Copper; and
- Zinc.

Ecological Setting - The North Area soils represent areas that are topographically higher than the wetland sediments, but the area is generally contiguous. The North Area is subject to flooding from extreme rainfall or storm surges. Therefore, the area does not represent an upland terrestrial area, but more of a transitional area between wetland sediments and soils. The dominant crustacean such a transitional area is typically the fiddler crab (Uca spp.). Fiddler crabs were noted by the field crew to be present during sample collection. There are several species that inhabit Texas marshes, but the most common are *Uca rapax, Uca panacea, Uca mimax, and Uca spinacarpa* (Barnwell and Thurman, 1984). They are detritivores that feed near their burrows during low tide by separating organic detritus from sediment using specialized legs (Barnwell, 1968).

Other burrowing crabs that typically inhabit the high marsh environments are the marsh crab (*Sesarma cinereum*) and the land crab (*Cardisoma guanhumi*). The primary food source for the marsh crab is *Spartina* detritus, but it will eat small fiddler crabs when they are available (Seiple, 1979). The land crab is an omnivorous scavenger. Both species are eaten by mammalian predators, such as raccoons and coyotes. Other crustaceans often present in the transitional area are hermit crabs (*Clibanarius vittatus* and *Pagurus longicarpus*) (Young, 1978). Hermit crabs move frequently between the intertidal marsh and the high marsh and are omnivorous scavengers that seek out animal tissues and other organic detritus.

Analytical Chemistry Results - In general, the 2010 BERA analytical results for North Area soils are lower than the analytical results from the RI data collected in 2009. As shown on Table 5, the BERA data show exceedances of the benchmarks for barium, chromium, copper and zinc in at least one sample. Detections of zinc exceeded the screening benchmark in five (5) of six (6) Site samples and two (2) of three (3) reference samples. The COPECs 4,4'-DDT and Aroclor-1254 are the only two (2) organic compounds for this area and their concentrations exceed marine sediment benchmarks in at least one sample (Table 5). These benchmarks are ERL values and represent conservative screening criteria (Long et al., 1995). A concentration gradient for the two (2) organic COPECs was not apparent from the 2010 data. As shown on Table 5, concentration gradients were evident for the inorganic constituents. For example, zinc concentrations in North Area soils ranged from 62.3 to 5,770 milligram/kilogram – Dry Weight (mg/kg-DW) and from 63.1 to 501 mg/kg-DW in reference samples. Barium concentrations in North Area soils ranged from 52.2 to 502 mg/kg-DW and from 172 to 340 mg/kg-DW in reference samples.

Toxicity Results - The results from the North Area soils toxicity tests showed no statistically significant differences in toxicity results using the test species *Neanthes arenaceodentata* in site samples when compared to the reference locations. As shown on Tables 4 and 5, mean survival rates ranged from 76% to 96% in the North Area soil samples. The toxicity results did not consistently correlate with the results of the analytical chemistry. For example, reference concentrations of barium and zinc were elevated in soil sample NAS07, but mean survival of *Neanthes arenaceodentata* in that sample was high (92%). Contrastingly, reference concentrations of all inorganic COPECs were below the TCEQ's soil benchmarks, except for chromium, and below all of the marine sediment benchmarks (including chromium) for sample NAS09, yet this sample produced the highest mortality (60% mean survival).

3.3.2 Wetland Sediment

Wetland sediment was evaluated through the collection and analysis of seven (7) samples from the Site (EWSED01 through EWSED07) and two (2) samples from a reference area (EWSED08 and EWSED09), as shown on Figure 4. All of the sediment samples were collected from the 0 to 0.5-foot depth interval. Sediment pore water was extracted and analyzed for COPECs for all but one sediment sample (EWSED05), which was too dry to extract pore water. There was not a formal assessment of benthic invertebrates in the samples during the field event; however, polychaete worms and fiddler crabs were observed in all of the wetland sediment sample locations, including the reference locations. The COPECs for the wetland bulk sediment and pore water are as follows:

- 2-Methylnaphthalene;
- 4,4'-DDT;
- Acenaphthene;
- Acenaphthylene;
- Anthracene;
- Arsenic;
- Benzo(a)anthracene;
- Benzo(a)pyrene;
- Benzo(g,h,i)perylene;
- Chrysene;
- Copper;
- Dibenz(a,h)anthracene;
- Endrin aldehyde;
- Endrin ketone;
- Fluoranthene;
- Fluorene;
- gamma-Chlordane;
- Indeno(1,2,3-cd)pyrene;
- Lead;
- Nickel;
- Phenanthrene;
- Pyrene; and

- Zinc.

Ecological Setting – As described in Section 1.3, the wetland sediment area can be considered a salt panne. In general, the intertidal zone receives nutrients flushed from the supra-tidal zone and nutrients that are filtered out of near-shore waters; however the area is high in hyper-saline and conditions are considered harsh. Similar to the North Area soil, the dominant crustacean in this area is the fiddler crab (*Uca* spp.). Juvenile blue crabs, which may also be present, take refuge in the marsh areas, but migrate to the subtidal zone as they get larger. Mud crabs (*Neopanope texana* and *Panopeus herbstii*) typically live in shallow mud or under shoreline debris and feed on oyster spat, barnacles, snails and smaller crabs (Reames and Williams, 1983). Other crustaceans that may live in the area are hermit crabs (*Clibanarius vittatus* and *Pagurus longicarpus*) (Young, 1978), and mud shrimp (*Callianassa jamaicense*). All are omnivorous scavengers that feed on organic detritus trapped in marsh sediment (Fotheringham, 1975).

Analytical Chemistry Results - In general, the 2010 BERA analytical results for wetland sediments were lower than the analytical results from the RI data collected in 2008. As shown on Table 6, there were exceedances of the sediment benchmarks for several individual PAHs and metals (lead, nickel and zinc) in one or more of the BERA samples. The only exceedances of surface water benchmarks from Site wetland sediment pore water were for endrin aldehyde, endrin ketone, copper, and zinc. The only exceedances of either sediment or surface water benchmarks in the reference samples were 4,4'-DDT in sediment; and 4,4'-DDT, endrin aldehyde, and nickel in sediment pore water. As shown on Table 6, concentration gradients were identified for the majority of the COPECs. For example, zinc concentrations in wetland sediments ranged from 70.1 to 959 mg/kg-DW in Site samples and from 68.3 to 94.3 mg/kg-DW in reference samples. Copper concentrations in wetland sediments ranged from 13.3 to 30.7 mg/kg-DW in Site samples and from 11.7 to 15.8 mg/kg-DW in reference samples. Copper concentrations in sediment pore water ranged from undetected to 0.00702 milligram/liter (mg/L) in Site samples and from undetected to 0.00137 mg/L in reference samples.

Detailed information on sediment grain size and SEM/AVS analytical results are presented on Table 7 and Table 8, respectively. The SEM/AVS ratios presented in Table 8 are all above 1.0, except for EWSED08 (with an SEM/AVS ratio of 0.157), which indicates that the potential exists for metal toxicity since sufficient AVS to completely form insoluble metal sulfides is not present. However, sediment organic carbon can also bind the free metals and reduce their availability to aquatic organisms. The ratio of “excess” SEM to the fraction organic carbon content of sediment was below 130 micromoles per gram organic carbon ($\mu mol/g_{oc}$), the concentration predicted to be non-toxic by the EPA (2005), for six (6) of seven (7) Site samples. Also, the remaining Site sample (EWSED06) had an organic carbon-normalized excess SEM ratio of 168, which is at the low end of the range where the prediction of toxicity is uncertain (130 to 3,000 $\mu mol/g_{oc}$; EPA, 2005). The sediment grain size data presented in Table 7 are fairly consistent between locations, except for the relatively high fraction of gravel and low fraction of clay found at EWSED02 and EWSED03 as compared to the opposite situation (low fraction of gravel and high fraction of clay) at EWSED01, EWSED04, EWSED06, EWSED07, and EWSED09.

Toxicity Results – Tables 4 and 6 include a summary of the wetland sediment toxicity testing (bioassay) results. For the polychaete, *Neanthes arenaceodentata* and the amphipod, *Leptocheirus plumulosus*, there were no statistically significant differences between the seven (7) Site samples (EWSED01 through EWSED07) and the two (2) reference samples (EWSED08 and EWSED09) for the survival or growth endpoints. Insufficient offspring were produced for a statistical analysis of the reproduction endpoint for amphipods.

The results of the toxicity study did not consistently correlate well with the results of the analytical chemistry. For example, a zinc concentration of 115 mg/kg-DW at EWSED01 was associated with *Leptocheirus plumulosus* survival of 35%, while a zinc concentration of 595 mg/kg-DW at EWSED05 was associated with *Leptocheirus plumulosus* mean survival of 38%. These results serve to illustrate the fact that toxicity test organism responses reflect exposure to the full balance of potential stressors, not individual COPECs. These stressors include Site COPECs and other types of stressors (e.g., elevated salinities) that can exert independent and collective effects. Thus, caution should be exercised when interpreting such data regarding the co-occurrence of screening benchmarks.

3.3.3 Intracoastal Waterway Sediment

Intracoastal Waterway sediment was evaluated through the collection and analysis of five (5) samples from the Site (EIWSED01 through EIWSED05) and two (2) samples from a reference area (EIWSED06 and EIWSED07), as shown on Figure 5 and Figure 6, respectively. All of the sediment samples were collected from the 0 to 0.5-foot depth interval. There was not a formal assessment of benthic invertebrates in the samples during the field event; however, benthic invertebrates were observed in all of the Intracoastal Waterway sediment samples, including the reference samples. The most abundant organisms appeared to be polychaete worms (*Neanthes spp.*). Additionally, mud crabs and snapping shrimp were observed by the field crew in some of the sediment samples. Sediment pore water was extracted from all seven (7) locations and analyzed for Site COPECS. The COPECs for the Intracoastal Waterway bulk sediment and pore water are as follows:

- 4,4'-DDT;
- Acenaphthene;
- Benzo(a)anthracene;
- Chrysene;
- Dibenz(a,h)anthracene;
- Fluoranthene;
- Fluorene;
- Hexachlorobenzene;
- Phenanthrene; and
- Pyrene.

Ecological Setting - The benthic communities found in the Intracoastal Waterway and Oyster Creek in the Site vicinity are very similar to the communities that would be found in a primary or secondary bay on the Texas Gulf Coast. The Intracoastal Waterway represents a diverse ecological system. Water depths, vehicle traffic, reduced light penetration, and higher than normal tidal energy prevent submerged vegetation from growing in the Intracoastal Waterway near the Site. The absence of attached vegetation that provides food and shelter decreases the number of invertebrate species that can utilize the habitat. Most of the epibenthic invertebrates that utilize the subtidal zone in the Intracoastal Waterway are migrants. In areas where tidal energy is reduced, sediment and organic detritus can accumulate and create a habitat for benthic infauna (Heald, 1971). A summary of potential ecological receptors typically present in Texas bay systems is presented below. These species may or may not be present in the Intracoastal Waterway in the site vicinity.

The most common invertebrates in the subtidal zone are the micro- and macroinfauna. Microinfauna includes bacteria, flagellates, diatoms, and small worms and may represent a significant portion of the infaunal biomass. The macroinfauna (> 0.5 mm) includes polychaete worms, copepods, gastropods, amphipods, and isopods. Parchment worms (*Chaetopterus variopedatus*) and lugworms (*Arenicola cristata*) are tube-dwelling polychaete worms that are common in the subtidal sediment. Other polychaete worms are *Eteone heteropoda*, *Laeonereis culveri*, *Neanthes succinea, Ceratonereis irritabilis*, and *Capitella capitata*. *E. heteropoda* and *C. capitata* are deposit feeders. The other polychaetes are active predators and feed on other invertebrates.

Bivalves and gastropods are also commonly abundant on the subtidal bottom. Most live in the sediment and communicate with the overlying water through a siphon. Burrowing bivalves that are common in muddy sediment are the stout razor (*Tagelus plebeius*), jackknife clam (*Ensis minor*), and angelwing (*Crytopleura costata*). Other bivalves that occur in the shallow subtidal zone are the constricted macoma (*Macoma constricta*), dwarf surf clam (*Mulinia lateralis*), and southern quahog (*Mercenaria campechiensis*). The coot clam (*Mulinia lateralis*) is a prolific member of the mud bottom community and serves as an important food source for diving ducks and shorebirds.

Gastropods that may live on shallow subtidal bottom are the predatory whelks *Busycon spiratum* and *Busycon contrarium.* The bubble shell (*Bulla striata*), virgin nerite (*Neritina virginea*), and mud snail (*Nassarius vibex*) are also found on shallow mud bottoms.

The most common large invertebrates typically present on the subtidal bottom are adult blue crabs (*Callinectes sapidus*) and penaeid shrimp (Powers, 1977). Blue crabs are good swimmers and are highly mobile, but will burrow into soft mud when shelter is not available. They are omnivorous scavengers that selectively feed on organic particles and soft-bodied invertebrates (Odum and Heald, 1972; Hamilton, 1976). Adult white shrimp (*Litopenaeus setiferus*) and brown shrimp (*Farfantepenaeus aztecus*) can be seasonally abundant on the subtidal bottom.

They are omnivorous scavengers and grazers that feed on algae and organic detritus that accumulate as a flocculent in upper centimeter of sediment.

Analytical Chemistry Results - Table 9 provides a summary of the Intracoastal Waterway sediment data used in the original gradient determination (i.e., for the Final BERA Work Plan & SAP [URS, 2010a]) and the Intracoastal Waterway sediment analytical results generated from the BERA sampling. Table 9 also compares the TCEQ's marine sediment benchmarks and marine surface water benchmarks (TCEQ, 2006) to the 2010 BERA bulk sediment and pore water data, respectively. Analytical results from the 2010 BERA sampling of Intracoastal Waterway sediment and associated reference sediment are presented in Figure 5 and Figure 6, respectively.

In general, the 2010 analytical results for Intracoastal Waterway sediments were lower than the analytical results from the RI data collected in 2008. There were no exceedances of the marine surface water benchmarks in sediment pore water. The only exceedances of sediment benchmarks were in sample EIWSED02 (4,4'-DDT, acenaphthene, and fluorene). As shown on Table 9, concentration gradients were identified for the majority of Site COPECs. For example, fluoranthene concentrations in Intracoastal Waterway sediments ranged from 0.074 to 0.52 mg/kg-DW in Site samples and from 0.018 to 0.0019 mg/kg-DW in reference samples.

Toxicity Results - Table 9 includes a summary of the Intracoastal Waterway sediment toxicity testing (bioassay) results. For the polychaete, *Neanthes arenaceodentata* and the amphipod *Leptocheirus plumulosus,* there were no statistically significant differences between the five (5) Site samples (EIWSED01 through EIWSED05) and the two (2) reference samples (EIWSED06 and EIWSED07) for the survival or growth endpoints. Insufficient offspring were produced for a statistical analysis of reproduction for the amphipod.

The results of the toxicity study did not consistently correlate well with the results of the analytical chemistry. For example, a fluoranthene concentration of 0.52 mg/kg-DW at EIWSED02 was associated with *Leptocheirus plumulosus* mean survival of 64%, while a lesser (i.e., more than seven-fold) fluoranthene concentration of 0.074 mg/kg-DW at EIWSED04 was associated with *Leptocheirus plumulosus* mean survival of 42%.

3.3.4 Surface Water

Wetland and pond surface water was evaluated through the collection and analysis of three (3) samples from the Site (EWSW01, EWSW03, and EWSW04), as shown on Figure 7. Surface water was not available at reference location EWSW02 (Figure 7). In general, surface water in the wetland area was not consistently present, and when present becomes highly saline as it rapidly evaporates. Surface water salinities measured by Benchmark Ecological Services, Inc. for EWSW01, EWSW03, and EWSW04 were 43‰, 27‰, and 42‰, respectively (Table 2). These salinities were consistent with salinities measured in the laboratory by PBS&J Environmental Toxicology Laboratory (approximately 40‰, 30%, and 39‰ [as received] for EWSW01, EWSW03, and EWSW04, respectively; see Appendix B). The COPECs for the surface water samples were location-specific. For EWSW01, the COPECs consisted of total acrolein and dissolved copper. The COPEC for EWSW03 was dissolved copper and the COPEC for EWSW04 was dissolved silver. The original risk question that addressed the abundance, diversity, productivity and function of the fish community is not applicable because of the harsh conditions and intermittent presence of the surface water in a salt panne; however, the 48 hour toxicity tests using the brine shrimp as a test species addresses any potential toxicity to water column invertebrates that may inhabit the intermittent ponds.

Ecological Setting - As discussed in Section 1.3, the wetlands area is indicative of marsh flats, which contain shallow pools and salt pannes. A salt panne is periodically flooded by tidal events that bring fresh sea-borne nutrients, small fish, and invertebrates. When these shallow pools evaporate, salty brine remains. These areas in the wetlands often dry out completely, creating even harsher conditions. When the seawater evaporates, the salts remain and accumulate over many tidal cycles. The difficult environs of the salt panne usually have soils that are frequently waterlogged, making them devoid of oxygen. The high salt concentrations, waterlogged soils, and warm waters associated with salt pannes mean that not many plants can survive and the biological diversity is low. The surface water samples were taken from these shallow pools with elevated salinity.

Analytical Chemistry Results - Table 10 provides a summary of the wetland surface water results considered in the original gradient determination (i.e., for the Final BERA Work Plan & SAP [URS, 2010a]) and the wetland surface water analytical results generated from the BERA sampling. Analytical results from the 2010 sampling of wetland surface water are also presented in Figure 7. The reference location EWSW02 was dry and could not be sampled for surface water. Because these pools are intermittent, acute surface water criteria (TCEQ, 2005) were used for comparison. There were no exceedances of surface water acute criteria in any of the samples.

Toxicity Results – There is considerable uncertainty with the surface water toxicity test using the test species *Artmeia*. The test was run three times for a duration of 96 hours; however, the results were not reproducible between the three tests for the three samples. Based on discussions during a meeting on December 1, 2010 with GRG, their consultants, TCEQ and EPA, it was decided that the toxicity testing would be presented based on the results at 48 hours.

EWSW-01 showed acceptable laboratory control survival for tests 1 (100%) and 3 (90%) at 48 hours with no indication of toxicity from the Site surface water at any dilution (survival ranged from 80% - 100%).

EWSW03 showed acceptable laboratory control for test 1 (100%) and test 3 (94%) at 48 hours with no indication of toxicity from the Site surface water at any dilution (survival ranged from 98% - 100%) in test 1, but low survival in test 3 in all of the test dilution (0% to 70%). It is unknown why the outcomes of the two tests were inconsistent.

EWSW04 showed acceptable laboratory control for test 1 (99%), but only 86% for test 3 at 48 hours. There was no indication of toxicity from the Site surface water at any dilution (survival ranged from 98% - 100%) in test 1. Survival in test 3 ranged from 82% to 98%.

4.0 RISK CHARACTERIZATION – RISK ESTIMATION AND RISK DESCRIPTION (STEP 7)

The data collected to support the BERA were designed to address the ecological risk questions first presented in the Final BERA Work Plan & SAP (URS, 2010a):

1. Does exposure to COPECs in soil adversely affect the abundance, diversity, productivity, and function of the soil invertebrate community?

2. Does exposure to COPECs in bulk sediment and pore water adversely affect the abundance, diversity, productivity and function of the benthic invertebrate community?

3. Does exposure to COPECs in surface water adversely affect the abundance, diversity, productivity and function of the fish community?

Overall, the data met the data quality objectives identified in the Final BERA Work Plan & SAP (URS, 2010a) and are adequate for evaluation and risk characterization in the BERA as presented in the Final PSCR (URS, 2010c). However, the assumption presented in the Final BERA Work Plan & SAP (URS, 2010a) that any impacts on toxicity would be solely due to Site COPECs proved to be incorrect. Similar inconsistent and modest toxicity was associated with soils/sediments from both the reference locations and the Site locations.

4.1 NORTH AREA SOILS

The toxicity testing of *Neanthes arenaceodentata* over a 21-day exposure period showed no statistically significant differences between the North Area soil samples and the reference location soil samples. As summarized on Table 4 and Table 5, mean survival in the six (6) Site samples ranged from 76% to 96% and mean survival in the three (3) reference samples ranged from 60% to 92%. The growth data showed a similar relationship between the Site and reference samples. The results of the toxicity study did not always correlate well with the results of the analytical chemistry as compared to screening benchmarks. For example, while concentrations of barium and zinc were elevated in reference soil sample NAS07, the mean survival of *Neanthes arenaceodentata* in that sample was high (92%). Contrastingly, reference location sample

(NAS09) concentrations of all metal COPECs, except chromium, were below the TCEQ's soil benchmarks, yet this sample had the highest mortality (60% mean survival). The chromium detected in sample NAS09 (13.3 mg/kg) is greater than the soil benchmark of 0.4 mg/kg, but well below the marine sediment benchmark of 81 mg/kg (Table 5).

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The BERA concludes that there are no Site-related adverse effects when comparing the North Area samples to the reference samples and that exposure to COPECs in the North Area soil does not adversely affect the abundance, diversity, productivity and function of the sediment invertebrate community. Note that the original risk question was directed to soil invertebrates (earthworms), but through the BERA process it was determined that the habitat is not conducive to earthworms and is more applicable to saline tolerant sediment invertebrates.

4.2 WETLAND SEDIMENTS

Toxicity testing of the wetland sediments was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus*. Table 4 and Table 6 summarize the toxicity test results for these samples. There were no statistically significant differences between the Site wetland sediment samples and the reference wetland sediment samples. The comparison of bulk sediment and sediment pore water concentrations to screening benchmarks (Table 6) generally indicates a relatively low bioavailability and low potential for sediment toxicity. The SEM/AVS ratios presented in Table 8 are all above 1.0 (except for EWSED08 with an SEM/AVS ratio of 0.157), which indicates that the potential exists for metal toxicity since sufficient AVS to completely form insoluble metal sulfides is not present. However, sediment organic carbon can also bind the free metals and reduce their availability to aquatic organisms. The ratio of "excess" SEM to the fraction organic carbon content of sediment was below 130 micromoles per gram organic carbon ($\mu mol/g_{oc}$), the concentration predicted to be non-toxic by the EPA (2005), for six (6) of seven (7) Site samples. Also, the remaining Site sample (EWSED06) had an organic carbon-normalized excess SEM ratio of 168, which is at the low end of the range where the prediction of toxicity is uncertain (130 to 3,000 $\mu mol/g_{oc}$; EPA, 2005).

Because the results did not point to any single chemical stressor or physical parameter as the cause of any toxicity, further statistical analysis was conducted. Multiple linear regression

(MLR), a form of multivariate statistical analysis, was selected to explore potential associations[1] or dependencies between the various physical and chemical parameters (i.e., the independent variables) and the toxicity test endpoints (i.e., the dependent variables). Association does not prove causality, but causality cannot exist without association. The physical parameters evaluated in the MLR analysis included the sediment grain size percentages. The chemical parameters evaluated included total organic carbon (TOC), results of the AVS-SEM analysis, and the Site COPECs. Details of the MLR analysis, as well as input files, raw data output, and select linear regression graphs are provided in Appendix C. The MLR analysis did not find any significant associations between PAHs and most metals for either toxicity test endpoint for either sediment test species.

Overall, the results of the MLR analysis indicate that some of the physical and chemical parameters, when considered individually or together in certain subsets, have statistically significant associations with the two toxicity test endpoints (i.e., survival and growth). Zinc concentration indicated a statistically significant negative association (indicating a potential effect) and TOC indicated a statistically significant positive association with growth, but not percent survival, when regressed individually for *Leptocheirus plumulosus*. However, the adjusted correlation coefficients for these instances are low (i.e., 50% or less) indicating weak correlations. Neither zinc nor TOC indicated statistically significant associations with growth (as measured by dry weight) or percent survival for *Neanthes arenaceodentata*. Therefore, only one of four possible outcomes indicated statistically significant associations.

A regression subset with statistically significant associations to survival for *Neanthes arenaceodentata* included TOC (positive) and percent medium gravel (positive). Similarly, the subset of TOC (positive), copper SEM concentration (negative), lead SEM concentration (positive), nickel SEM concentration (negative), and the sum of SEM metals' concentrations divided by the AVS concentration (negative) indicated statistically significant associations to dry weight for *Leptocheirus plumulosus*. A regression subset with statistically significant associations to survival for *Neanthes arenaceodentata* included percent clay (negative), percent

[1] "Associations", rather than "correlations", is the preferred term for the results of a multiple linear regression. An analysis of variance test that provides a correlation coefficient is a different statistical technique.

fine gravel (negative), percent coarse sand (positive), percent fine sand (negative), and percent medium sand (negative).

These conclusions are somewhat confounded by the fact that no parameter's individual statistically significant association is ever true for both endpoints for the same organism or both organisms. These results may be related to the small number of dependent variables (i.e., nine values per toxicity test endpoint) that creates a weakness of the MLR analysis.

The risk characterization results conclude that mortality and decreased growth of surviving organisms observed in the wetland sediment toxicity tests cannot be attributed to any one physical and/or chemical parameter. Considering the results as a whole, it is possible that a combination of parameters, such as TOC, certain sediment grain sizes, and contaminants (either inorganic or anthropogenically organic) may have influenced the pattern and degree of mortality of *Leptocheirus plumulosus* across all site and reference location wetland sediment samples.

Ultimately, the BERA concludes that there are no Site-related adverse effects when comparing the Site wetland area samples to the reference wetland sediment samples, and that exposure to COPECs in bulk sediment and pore water does not adversely affect the abundance, diversity, productivity and function of the benthic invertebrate community.

4.3 INTRACOASTAL WATERWAY SEDIMENTS

Toxicity testing of the Intracoastal Waterway sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus*. Table 4 and Table 9 summarize the toxicity test results for these samples. There were no statistically significant differences between the Site Intracoastal Waterway sediment samples and the reference location Intracoastal Waterway samples. The comparison of bulk sediment and sediment pore water concentrations to screening benchmarks (Table 9) indicates a low potential for sediment toxicity.

The BERA concludes that there are no Site-related adverse effects when comparing the Site Intracoastal Waterway samples to the reference Intracoastal Waterway samples and that exposure to COPECs in bulk sediment and pore water does not adversely affect the abundance, diversity, productivity and function of the benthic invertebrate community.

4.4 SURFACE WATER

Only three of the four scheduled surface water samples from the wetland area were collected, and, as discussed in Section 1.3, the wetland area sampled can be categorized as a salt panne, with limited ecological resources. There were no exceedances of the surface water acute criteria for the COPECs, acrolein, copper or silver (Table 10) and the toxicity tests were not acutely toxic at a 48-hour test duration. The original risk question that addressed the abundance, diversity, productivity and function of the fish community is not applicable because of the harsh conditions and intermittent nature of the surface water in a salt panne; however, the 48 hour toxicity tests using the brine shrimp as a test species indicates a low potential for toxicity from exposure to surface water.

5.0 UNCERTAINTY ANALYSIS (STEP 7 CONT.)

Uncertainties are associated with each step in the BERA process, including problem formulation, ecological effects evaluation, exposure estimation, and risk characterization. According to the USEPA (1997), "Uncertainty should be distinguished from variability, which arises from true heterogeneity or variation in characteristics of the environment and receptors." The interpretation of the BERA results are aided by a recognition and understanding of the source and nature of the known set of uncertainties that can influence the risk characterization results.

5.1 UNCERTAINTIES IN PROBLEM FORMULATION

Potential uncertainties associated with the problem formulation phase of the BERA are related to the identification of COPECs, contaminant fate and transport, and exposure pathways.

5.1.1 COPEC Selection

The BERA COPECs were identified using data obtained from the RI and presented in the Nature and Extent Data Report (PBW, 2009). These COPECs and others were identified as those with a potential to cause adverse effects as described in the Final SLERA (PBW, 2010). Elimination of certain COPECs during the SLERA streamlined the focus of the BERA to the COPECs that required additional investigation. Uncertainty may be associated with the environmental sampling for the RI and the BERA. Uncertainty may also be associated with the laboratory analysis of the Site samples, but there are a number of quality control and quality assurance measures that minimize errors and uncertainty.

It is believed that uncertainty associated with COPEC selection for the BERA is minimal since: 1) the SLERA process is, by design, conservative to avoid underestimating potential risk by inadvertently eliminating any COPECs, and 2) COPECs evaluated in the BERA were the more toxic (relatively) and prevalent compounds (both frequency and concentration) at the Site. Furthermore, if the presence of a chemical were responsible for decreased survivorship and growth, a statistical difference would have been more apparent between Site and reference samples, unless of course the compound(s) was present at both Site and reference sampling locations at similar concentrations.

5.1.2 COPEC Gradient

The 2010 sampling locations were chosen based upon the RI data obtained between 2006 and 2008. Between the RI sampling in 2006-2008 and the BERA sampling in 2010, there has been periodic flooding, in addition to the landfall of Hurricane Ike in September 2008. The potential impacts of these events on COPEC concentrations is unknown. However, the COPEC concentrations in BERA samples were generally less than COPEC concentrations in RI samples. If COPEC concentrations across the Site uniformly decreased because of flooding events, then the BERA sample locations based on RI data are equally representative of Site conditions, as if the locations had been randomly chosen. There is potential uncertainty in the true representativeness of the BERA COPEC concentrations, but it is considered to be minimal. The COPEC concentrations gradients are shown on Tables 5, 6 and 9. The COPECs are adequately represented as being present at high, medium and low concentrations in relation to one another, i.e., a high concentration is the highest of the detected concentrations, but may not be considered high when compared to a benchmark. The presence of the concentration gradients meets the study objectives and there is little uncertainty associated with the presence of the concentration gradients for the COPECs.

5.1.3 Reference Sample Location Selection

Sediment reference locations were chosen as part of the initial investigation prior to the initiation of the ecological risk assessment activities. The soil reference area was selected during the RI field work. As recommended by EPA guidance (EPA, 2002), the ideal background reference areas should have the same physical, chemical, geological, and biological characteristics as the site being investigated, but without being affected by activities on the site. The reference areas were purposefully chosen out of the area of Site influence, but in areas that were grossly similar to the Site. There were no visible signs of disturbance, impact, or debris at any of the reference areas.

The reference locations are in the proximity of the Site where they are similarly influenced by storm surges and rain events, but are not so close in proximity to be influenced by site activities, as evidenced by data collected during the RI (PBW, 2009). The reference locations for the wetland sediment, North Area soils, and Intracoastal Waterway are considered appropriate and valid as an "ideal" background reference area as demonstrated by the low detections of chemicals, and similar physical and chemical characteristics as described above. As such, there is little uncertainty associated with using the reference samples for comparison to Site samples in the BERA.

5.2 UNCERTAINTIES IN EXPOSURE ANALYSIS AND ECOLOGICAL EFFECTS EVALUATION

This section discusses the uncertainties in the exposure analysis and ecological effects evaluation phases of the BERA. Exposure can be expressed as the co-occurrence or contact of the stressor with the ecological components, both in time and space (EPA, 1998). Uncertainties in the exposure analysis phase are centered on the quantification of the magnitude and patterns of exposure as they relate to the risk questions developed in the problem formulation phase. For this BERA, site-specific exposure response information was obtained by evaluating measurements of direct toxicity by multiple lines of evidence. The potential for confounding stressors that might influence the exposure response in the toxicity tests are discussed in this section.

5.2.1 Bioavailability

The uncertainty of the amount of the COPEC that is bioavailable to the ecological receptors is minimized in this BERA through the use of the whole sediment toxicity testing. The placement of the test organisms into the sediment creates an exposure potential that mimics the environment. Additionally, the sampling of pore water presents an additional line of evidence for bioavailability potential. When the Site pore water concentrations are compared to chronic surface water criteria, there were a few exceedances (e.g., endrin aldehyde in the pore water from the wetland sediment); however, these exceedance do not correlate with toxicity especially when considering the similar results from the Intracoastal Waterway toxicity tests with no exceedances of marine surface water criteria compared to the pore water. This indicates that the bioavailable fraction of the chemicals is not a unique or significant contributor to toxicity in the Site or reference locations from either the Intracoastal Waterway or the wetlands sediments.

5.2.2 Synergistic or Antagonistic Effects of Constituents

Some constituents will vary in toxicity depending on the presence of other constituents, either by increasing absorption, uptake or toxicity (synergistic) or by decreasing absorption, uptake, or toxicity (antagonistic). The relationships between constituents are poorly understood, except for the select few that have been studied. In addition to constituent interactions, other environmental factors (total organic carbon, sulfide, pH, conductivity, etc.) can either increase or decrease the absorption, uptake, or toxicity of a constituent. The magnitude of these uncertainties is unknown for most constituents.

5.2.3 Naturally Occurring Organisms

The possibility that naturally-occurring benthic invertebrates might have influenced the test organisms through predation or competition for food is unlikely. Records from PBS&J Environmental Toxicology Laboratory document that no invertebrates other than the test organisms were observed in the samples after test termination. Additionally, all of the samples were press-sieved (thereby likely eliminating predators) except for the heavy clay North Area soils that were hydrated for the 21-day polychaete test.

5.2.4 Laboratory Control Organisms

The uncertainties associated with the performance of the laboratory controls are minimal. All of the laboratory controls showed acceptable survival and growth. The average survival of *Neanthes arenaceodentata* in the controls ranged from 96% to 100%, whereas the average survival of *Leptocheirus plumulosus* in the controls was 81.5%. These results indicate that *Leptocheirus plumulosus* was more sensitive than *Neanthes arenaceodentata* to test conditions even in an optimal control medium.

5.2.5 Test Species

Two species were ultimately used in the sediment and soil toxicity testing (*Leptocheirus plumulosus* and *Neanthes arenaceodentata*) and one species was chosen for the surface water testing (*Artemia salina*). The choice of a test organism has a major influence on the relevance, success and interpretation of a test. Ideally, a test organism for use in tests should have: 1) a toxicological database demonstrating relative sensitivity to a range of contaminants of interest;

2) be in direct contact with the medium of interest; 3) be readily available from culture; 4) be easily maintained in the laboratory; 5) have a broad geographical distribution, be indigenous to the site being evaluated, or have a niche similar to organisms of concern (e.g. similar feeding guild or behavior to the indigenous organisms); 6) be tolerant of a broad range of physico-chemical characteristics (e.g., grain size); and 7) be compatible with exposure methods and endpoints.

Amphipods like *Leptocheirus plumulosus* have been used extensively to test the toxicity of marine, estuarine and freshwater sediments. *Leptocheirus plumulosus* is an infaunal amphipod intimately associated with sediment, due to its burrowing and sediment ingesting nature. *Leptocheirus plumulosus* is found in both oligohaline (0.5-5 ‰) and mesohaline (5-18 ‰) regions of estuaries on the East Coast of the U.S and is tolerant to a wide range of sediment grain size distribution (EPA, 2001). There is uncertainty with using *Leptocheirus plumulosus* in the toxicity testing at the Site because it is not native to the area and generally prefers a less saline environment. The salinities from the Site ranged from 27 to 43 ‰. In general, the amphipod *Leptocheirus plumulosus* did not perform as well in the reference samples or laboratory control samples as the polychaete worm *Neanthes arenaceodentata*. The mean survival for *Leptocheirus plumulosus* in the laboratory controls was 81.5%, whereas the mean survival for *Neanthes arenaceodentata* in the laboratory controls was 100% and 96%. These results may indicate that *Leptocheirus plumulosus* is a more sensitive test organism than *Neanthes arenaceodentata*.

As noted in the field notes during the BERA sampling, *Neanthes sp*. were noted as present in the Intracoastal Waterway sediments during field collection, indicating that this genus is indigenous to the area. *Neanthes arenaceodentata* has been documented as a reliable test organism, especially for the sublethal effect of growth in marine sediment bioassays (Moore and Dillon, 1993). Toxicity tests using *Neanthes arenaceodentata* were conducted at two exposure durations: 28 days and 21 days. This test organism is recognized as being used in 10 day and 20 to 28 days tests (ASTM, 2007). The use of *Neanthes arenaceodentata* as a test organism is associated with little uncertainty in the BERA.

As previously discussed, the BERA Work Plan & SAP (URS, 2010a) proposed the use of mysid shrimp as the test species, but when the surface waters were received at the laboratory the measured salinities were elevated beyond a level appropriate for the mysid shrimp. *Artemia salina* has an extreme euryhaline character. Its tolerance to salinity ranges from brackish water to saturated brines (Vanhaecke et al., 1981) and therefore was a logical choice as an alternate test organism for the highly saline surface waters at the Site. The performance of *Artema salina* as a test organism proved to be uncertain. The performances of the three tests were not consistent or reproducible. The ultimate conclusions of the surface water assessment is that the concentrations of the COPECs in the surface water were all less than acute criteria and the validity of the test at a 48-hour exposure was relatively stable between test runs.

5.3 UNCERTAINTIES IN RISK CHARACTERIZATION

Risk characterization is the final phase of the BERA and includes two major components: risk estimation and risk description. Risk estimation consists of integrating the exposure profiles with the exposure effects information and summarizing the associated uncertainties. The risk description provides information important for interpreting the risk results (EPA, 1997).

5.3.1 Uncertainties in the Comparison of Site Samples to Reference Locations

Because the reference samples were selected to be as identical as possible to the Site samples (minus the presence of site-related constituents) in regards to ecosystems, physical setting, and water chemistry per the Final BERA Work Plan & SAP (URS, 2010a), comparing the reference locations to the site samples imparts minimal uncertainty when evaluating the toxicity testing results. The magnitude of the uncertainty and influence on the BERA risk management conclusions is, therefore, expected to be minimal. Reference locations were utilized in the BERA for the study areas and media. The purpose of the reference samples was to be able to distinguish toxicity effects that would occur without the presence of the Site COPECs as defined by the SLERA. All of the results for the analytical chemistry and toxicity endpoints in Site samples should be considered in relation to the results from the reference samples. Both natural processes and anthropogenic processes could result in the presence of various stressors not associated with the Site:

- Natural processes could include deposition of naturally-occurring metallic minerals in sediments (e.g., silicon, calcium, sodium, potassium, phosphorus, carbonates, or sulfates); and

- Anthropogenic processes include deposition of chemicals from internal combustion engine exhaust, dredge spoil, mosquito spraying, highway runoff, and flood events. Marine engines have limited emissions controls for air emissions and no controls for particulate matter (EPA, 2010). Their emissions are therefore similar to what would be found on a busy highway.

5.3.2 Correlation of Toxicity Results with Other Factors

- The results of the toxicity studies are not always well correlated to the results of the analytical chemistry when compared to benchmarks. For example, while reference concentrations of barium and zinc are elevated in soil sample NAS07, the mean survival of *Neanthes arenaceodentata* in that sample was high (92%). Contrastingly, reference concentrations of all metal COPECs are below the TCEQ's soil benchmarks for soil sample NAS09, yet this sample evidenced the highest toxicity (60% mean survival). This lack of correlation is not surprising given the many variables associated with site-specific toxicity testing when compared with benchmark values, which are derived using various methods and data sets.

5.3.3 Uncertainties with Artemia Testing

- The surface water toxicity tests were run at a 96-hour duration, but there is uncertainty with the application of the 96-hour time frame for the evaluation of *Artemia salina* (brine shrimp). Test methods using *Artemia* are for 24 to 48 hour exposures (SPE, 1978). The exposure period of 24 hours is usually associated with the testing of freshly hatched individuals (nauplii). For the surface water toxicity testing completed for the Site, control failure did not occur at 24 hours (for all 3 test runs) or at 48 hours (from test runs 1 and 3 for samples EWSW01 and EWSW03). Sample EWSW04 in test 3 had a 86% survival for the control at 48 hours, but survival of *Artemia* in the Site surface water ranged from 82% to 98%. The 100% surface water samples (i.e., undiluted) for EWSW-01 and EWSW-04 exhibited survival rates of 97% and 99% in the first test, respectively, and 80% and 96% in the third test, respectively, after 48-hours, indicating consistency in the tests. Conversely, the 100% surface water sample (undiluted) for EWSW-03 exhibited survival rates of 100% and 0% in the first and third tests. The inconsistencies in the test results are likely due to the unreliability of *Artemia* as a test organism for tests of greater than 48 hours duration..

5.3.4 Toxicity Testing Duration

Ten-day tests are designed to be acute exposure tests for higher concentrations of toxic chemical compounds. Twenty-eight day tests are designed to be chronic exposure tests for lower concentrations of toxic chemical compounds to detect sublethal effects. The chronic exposure tests were selected as being the best measure of site conditions and potential toxicity from sediment samples for the Site.

If the conclusion is that the site COPECs are not the cause of mortality and decreased dry weight in the 28-day tests, then it follows that the COPECs would not be responsible for any observed adverse effects related to the COPECs in a proposed 10-day test. Sublethal and lethal effects caused by physical parameters (i.e., sediment composition) of the sediment samples would likely be less evident in the shorter test. Adverse effects, unless acute in nature, take time to become manifest and measurable, whether related to chemical presence or physical attributes (e.g., sediment grain size composition) in the organism's environment. The longer the bioassay test, the more exposure, and the more time there is for the adverse effect, be it slowed growth, delayed reproduction, or early death, to appear and be measured. Thus, the likely outcome of a shorter-duration test would be higher survival percentages and lower dry weight values (due to the shorter exposure time and lessened opportunity to feed and grow) among the replicates for both site samples and reference location samples.

Various studies were found in the literature to support the notion that variability (i.e., uncertainty) in toxicity testing results may be greater for chronic exposures, but toxic effects are likely to become more evident. In one study with a different amphipod species (Nipper et al., 1999), short-term survival was not affected by large variations in sediment grain size but was correlated to growth in the 28-day exposure. Additionally, survival was much lower in the longer-term study, even for the uncontaminated reference site and the least contaminated site. The results for these two sites also evidenced greater variability in the 28-day study as opposed to the 10-day study. Growth was not measured in the 10-day exposure tests, nor was reburial measured in the 28-day tests.

An EPA guidance document (EPA, 2001) on the method for chronic toxicity testing of sediments using the same amphipod species notes several studies that evaluated the comparative sensitivity between the acute and chronic tests. DeWitt et al. (1992; 1997) noted that the reproductive endpoint of the chronic test was more sensitive than the survival and growth endpoints of the acute and chronic tests. However, another study (McGee and Fisher, 1999) found the sublethal endpoints to be less sensitive than the survival endpoint.

6.0 RISK MANAGEMENT (STEP 8)

Risk management is a distinctly different process from risk assessment. The risk assessment establishes whether a risk is present and defines a range or magnitude of the risk (EPA, 1997). For this BERA, the risk characterization determined that there is no difference in the toxicity observed in samples collected at the reference locations and the Site for sediment/soil exposure, and that there was no toxicity associated with surface water. Because of the lack of Site-related toxicity, development of ecologically-based remediation goals was not necessary.

7.0 CONCLUSIONS

Toxicity testing of sediment was conducted using the 28-day whole-sediment tests for *Neanthes arenaceodentata* and *Leptocheirus plumulosus* using the wetland sediments and Intracoastal Waterway sediments. A 21-day whole sediment/soil toxicity test using *Neanthes arenaceodentata* was applied to the North Area soils. The bioassays for the surface water were conducted on brine shrimp (*Artemia salina*) and assessed at a 48-hour duration. Sample locations were chosen based on a concentration gradient of the chemicals of potential ecological concern (COPECs) identified in the SLERA.

The analysis of the toxicity and analytical data for all of the sediment areas showed that the most relevant comparison was of Site sample results to reference location samples results. This enables the comparison of results between Site samples and those reference samples that exhibit similar environmental conditions, but are not influenced by releases from the Site Ultimately, it was determined that there is no difference in the toxicity observed in samples collected at the reference locations and the Site for sediment/soil exposure and that there was no toxicity associated with surface water. Because of the lack of Site-related toxicity, development of ecologically-based remediation goals was not necessary.

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Tables

Figures

Appendix A
Environmental Chemistry

Appendix B
Toxicity Testing

Appendix C
Multiple Linear Regression Analysis - Wetland Sediment Toxicity Testing